INVESTIGATION OF ACOUSTIC WAVEFIELD DYNAMICS IN QUASI-REALISTIC OCEAN ENVIRONMENTS

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LONG-RANGE PROPAGATION

LONG-TERM GOAL

Our long-term goal is to provide a more complete understanding of the forward propagation of acoustic pulses in range dependent deep ocean environments at multi-megameter range scales.

SCIENTIFIC OBJECTIVES

There are two primary scientific objectives of this work: 1) to quantify the relevant ocean environment parameters that determine the range where wavefield predictability is lost (for a given transmitter center frequency and bandwidth), and 2) to develop a model based on geometric acoustics that facilitates our understanding of long range (multi-megameter) acoustic propagation. Both of these objectives play a role in the ultimate goal of understanding the limits of 'ray-based' acoustic tomography.

APPROACH

Traditionally, long range propagation of sound in the range dependent ocean waveguide has been treated using concepts developed from the field of waves in random media. Our approach attempts to use these traditional treatments as well as geometric concepts from the dynamical systems field to give insight as to what to expect upon propagating a single acoustic pulse, where the ocean environment is taken to be deterministic. For sound speed fluctuations due to mesoscale structure, it is anticipated that a deterministic-based treatment will be realizable in the near future.

The ray equations form a dynamical system that is known to be nonintegrable -- individual ray trajectories exhibit exponential sensitivity to the environment -- when the ocean has range-dependence. At any given range, a family of rays emanating from a point source form a Lagrangian manifold in a phase space that is composed of each ray trajectory's position, angle, and travel time. Folds of the manifold in this phase space dictate where caustics reside. Our numerical approach consists of solving the three dimensional ray dynamical system through a quasi-realistic ocean environment composed from the output of a eddy resolving ocean global circulation model. The locations where folds in the Lagrangian manifold occur are to be recorded, thus indicating the range dependence of both horizontal and vertical caustics generated due to the nonintegrable nature of the dynamical system. This approach will provide insight as to the importance of horizontal refraction due to mesoscale. The model is designed to be extensible, so that smaller scale ocean phenomena (e.g. internal waves) can be included.

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WORK COMPLETED

We have completed an investigation based on deriving a two dimensional horizontal plane wave parabolic equation that follows from the adiabatic mode approximation. The corresponding ray dynamical system is analyzed both theoretically and numerically for idealized mesoscale environments. This work is guiding us in the three dimensional numerical modelling effort as to the importance of horizontal refraction, at least for the near-axial rays. A paper detailing this effort has been submitted to JASA.

Using a semi-classical extension of this same model, and a horizontal parabolic equation model, extensive numerical simulations were performed to investigate the breakdown of ray theory. Direct wavefield comparisons indicate excellent agreement out to ranges of four megameters. Limits of predicting the wavefield beyond this range, are seen to be constrained by computational difficulties regarding the resolution of the Lagrangian manifold, as opposed to a global breakdown of ray theory due to the accumulation of phase errors. The preliminary results of this work have been presented at the June 1997 ASA meeting in State College, PA.

In regards to the vertical plane, a numerical method has been developed, based on the adiabatic approximation, for determining the range dependence of vertical scattering due to internal wave induced sound speed fluctuations. A simplified version of this method has been described in a paper submitted to JASA.

A three dimensional ray model is currently under development on the Cray T3E supercomputer at the Arctic Region Supercomputing Center at the University of Alaska. At this time, the model is still in the testing phase, and our first results quantifying the importance of horizontal vs vertical multiple forward scattering will be presented at the June 1998 ASA meeting in Seattle, WA.

IMPACT/APPLICATION

The three dimensional ray code is expected to contribute to the understanding of a planned long range, deep water, billboard array experiment, to be conducted by P. Worcester and collaborators. Our results concerning wavefield predictability are anticipated to have a strong impact on ray-based tomographic methods.

RELATED PROJECTS

Our work involves extensive collaborations with the following individuals: M. Brown, F. Tappert, and S. Tomsovic.

REFERENCES

R. Bleck and E. P. Chassignet (1994), in ``The Oceans: Physical Chemical Dynamics and Human Impact," The Pennsylvania Academy of Science, 18-39.

M. G. Brown (1994). A Maslov-Chapman wavefield representation for wide angle one-way propagation. Geophys. J. Int., **116**, 513-526.

S. Tomsovic and E. J. Heller (1993). Long-time semiclassical dynamics of chaos: the stadium billiard. Phys. Rev. E, **47**, 282-299.